

JISC DEVELOPMENT PROGRAMMES

Project Document Cover Sheet

Serving Maths PROJECT PLAN

Project

Project Acronym	Serving Maths	Project ID	
Project Title	Serving Maths in a distributed e-learning environment		
Start Date	1 st September 2004	End Date	31 st March 2005
Lead Institution	University of York		
Project Director	Gustav Delius		
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Partner Institutions			
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Programme Name (and number)	E-learning Tools for Learners and Teachers Distributed E-learning Programme		
Programme Manager	Richard McKenna		

Document

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Overview of Project

1. Background

E-learning and e-assessment meet special challenges when it comes to the teaching of mathematical skills. Special tools and systems have been developed by the subject community to address these challenges, many of them—including the systems presented here—very sophisticated. However, the widespread adoption of these tools has been hindered by a lack of standards and interoperability.

We will extend and adapt existing mathematical e-learning tools and systems, developed by members of the project team, to make them interoperable with other components of a managed learning environment, as well as with one another. This will be done using and extending e-learning standards and web service protocols.

We will extend the following existing systems and make them interoperable:

- AiM and CABLE are self-testing and assessment systems based on server-side marking using computer algebra, allowing for testing of higher mathematical skills;
- METRIC is a self-testing and mathematical learning system based on client-side marking implemented in Java, allowing for scalability and use off-line.
- WaLLiS is an interactive learning environment that focuses on providing adaptive and intelligent feedback for mathematics questions.
- Moodle is a user-friendly VLE with an assessment system that we will extend.

These tools have already been proven at several institutions to provide great pedagogical benefit to the learning experience of students of mathematics and related disciplines, both in higher education and at the school-university interface.

2. Aims and Objectives

Our aim is to provide lecturers with convenient and easy-to-use tools to create computer aided assessment questions for mathematics and to integrate them as seamlessly as possible into their existing teaching practice.

In the field of mathematics, a would-be author of question items currently faces a number of problems. The only generally available, interoperable, standards-compliant authoring tools will allow her to create questions of a general type, such as multiple-choice, textual input or numerical input. However, they will not allow her to format mathematical expressions, or to generate such expressions from parameter sets, or to create items that assess student answers in the form of such expressions. The overall aim of the project is to solve these problems, by pooling and enhancing the non-generic solutions already developed by members of the team.

It is our aim that the tools we develop will be easy to integrate into existing e-learning environments and existing assessment systems. They should be easy to install, either by an individual lecturer or centrally by a whole institution.

A further aim of this project is to make it easier for developers of e-learning tools to equip their tools with the extra capabilities required for mathematics.

Our objectives are:

1. To develop a Web Service for the delivery of mathematical expressions. This service will be able to be called by any e-learning tool; it will respond appropriately to the capabilities of the user's browser and to his/her preferences, and will provide a choice of input tools (some of which have already been developed by members of the team). It will make available free-floating mathematical tools developed by team members, as well as fronts ends to server-side computer algebra systems.
2. To produce an XML specification to represent mathematical questions. The specification will reflect the particular nature of the subject: specifically, the need to assess student answers that are in the form of mathematical expressions. This will be implemented in AiM, CABLE and METRIC. We shall work closely with the MathML, OpenMath and IMS communities internationally.
3. To develop an authoring tool for mathematics question items, providing teachers with simple interfaces that allow questions to be written without the need to become familiar with the underlying formats. This tool shall accept plug-ins for various question types.
4. To develop a web services protocol with which existing assessment systems can communicate with our mathematical assessment engines to allow them to incorporate mathematical questions into their quizzes.
5. To develop tools with which lecturers can seamlessly integrate computer aided assessment questions into their traditional problem sheets.

3. Overall Approach

Strategy and structuring

The project is based around 5 existing and three new software packages. The existing packages are

- AiM
- CABLE
- METRIC
- Moodle
- WaLLiS

The three new packages to be developed by the project are

- a question authoring tool with plug-ins for different question types
- a web service for representing mathematics on the web
- a tool allowing lecturers to manage both their conventional assignment questions and their computer aided questions and to combine them seamlessly into problem sheets.

The project will tie these tools together by several web services protocols and interoperability specifications:

- a web service protocol for communication between assessment systems and question engines

- a syntax specification and web service protocol for communication with the service taking care of the presentation of mathematics on the web
- a specification for mathematical questions

This structure of working on 8 independent software projects, tied together by web services protocols and interoperability specifications makes management of this project easier as would otherwise be the case for a project with a geographically distributed team.

The strong reliance on web service protocols and interoperability specifications however serves another purpose: it will make it possible for other mathematical software, not included in this project, to achieve interoperability with our tools by implementing the same protocols and specifications.

Scope and boundaries

The project is focused on the development and implementation of standards, services and implementations for authoring and deploying question test items in mathematics. Within this, our central concern is mathematical expressions: their generation, rendering and comparison as mathematical objects. The project is not concerned with wider e-learning issues in mathematics, such as microworlds, intelligent tutoring, course management or assessment of sustained mathematical argument.

Neither is the project committed to dealing with the issue of graphics in question tests. This issue has, however, been addressed by several of the individual team members in their non-generic projects, and the work may reveal opportunities to build on these achievements. Any such opportunities will be taken advantage of if time, and other project commitments, allows it.

Important issues and critical success factors

Interoperability lies at the heart of the project's aims, and indeed a large mid-project milestone has been scheduled that consists in demonstrating interoperability among all components developed thus far. Achieving interoperability is central to the project's success, as is **compliance** with existing and emerging standards (for example, those for QTI in general).

Of at least equal importance is **ease of use**. Since the project's overall aim is to enable colleagues to create mathematical question test items without becoming expert programmers, the ensemble of services, standards, implementations and authoring tools that the project produces must be usable in a natural and intuitive way, and without extensive training. Also, at the learner's end, the project's implementations must generate questions that are themselves easy to use. In particular, questions must test, as far as possible, the learner's knowledge of mathematics only, and not of specialised, non-intuitive notations and conventions.

Pedagogical soundness cannot be directly guaranteed, because it is always possible to use good tools badly. Nonetheless, the project's deliverables must *lend themselves* to pedagogically sound use. Specifically, they must enable the creation of cognitively rich question items that assess as many aspects as possible of mathematical thinking, at as many levels as possible in a Bloom-type taxonomy of objectives. Cognitive richness must come without a major cost in interoperability or ease of use, and must not require the author to

acquire arcane expertise. It must manifest itself in tasks for the learner whose richness of challenge lies solely in their mathematical content, and not in any fresh computational or user interface problems.

4. Project Outputs

The following is a list of deliverables, organized into 5 sections. The meaning of some of the items in the list will become clearer after the description of the 5 sections which follows the list.

1. **DOME: a web service for mathematical expressions**
 1. A syntax and protocol specification for the service
 2. An implementation of the service
 3. Client interfaces in
 1. Moodle
 2. AiM
 3. CABLE
 4. METRIC
 5. WaLLiS
 4. User documentation, website, support forum
 5. Developer documentation, SourceForge CVS repository
2. **Interoperability for mathematics questions**
 1. Workshop to discuss proposals for maths QTI
 2. A maths QTI specification
 3. Rendering and marking of maths QTI questions in
 1. AiM
 2. CABLE
 3. METRIC
 4. A community website and discussion forum about maths QTI
 5. A repository for maths QTI questions
3. **Authoring tools for mathematical assessment questions**
 1. maths QTI authoring tool with plug-in architecture
 2. Authoring tool plug-ins for
 1. differentiation questions
 2. integration questions
 3. matrix questions
 4. spread-sheet style questions
 5. adaptive questions
 3. Integration of authoring tool into Moodle
 4. Interface between authoring tool and maths QTI repository
 5. User documentation, website, support forum
 6. Developer documentation, SourceForge CVS repository
4. **Extensible assessment systems**
 1. Workshop about the architecture of extensible assessment systems
 2. A specification of a RemoteQuestionProtocol (jointly with APIS)
 3. Implementations of RQP server interfaces in
 1. AiM

2. CABLE
4. RQP client interfaces in
 1. Moodle
 2. METRIC
 3. WaLLiS
5. Developer documentation
5. **Computer aided problem sheets**
 1. Unified question management tool for both conventional and computerized problem
 2. Extension of Moodle VLE to manage and conduct assessment of problem sheets
 3. Teacher manual, Student manual, Collection of example problem sheets
 4. Developer documentation

We now describe each of the 5 main parts in more details, repeating some information from the project proposal.

DOME: a web service for the delivery of mathematical expressions

In order for any on-line learning material or tool to be useful for mathematics and science teaching it needs a way to allow the user to enter and view mathematical formulas. This is currently a problem for web-based solutions because the MathML standard is not yet sufficiently supported by most browsers. Many of the work-around solutions (like converting formulas to images or to HTML) are unsatisfactory because they do not meet accessibility criteria.

In order to deliver formulas appropriately to all users they need to be translated into a variety of formats depending on the capabilities of the user's browser and the user's preferences. A visually impaired user for example needs to be able to set an option to receive formulas in particularly large font size or have them delivered in the form required by a screen reader.

Most existing components of virtual leaning environments (bulletin boards and discussion forums, chat areas, messaging systems, collaboration tools and assessment tools) do not currently provide sufficient support for mathematics. One solution would be to replace all these components by ones suitable for mathematics. We propose an alternative and more feasible solution: We will develop a web service that can be called by any e-learning tool and takes care of all matters related to the display of mathematical expressions:

- managing user preferences and detecting the type of browser used,
- dynamically converting the expressions into the most suitable form, given the user's preferences and the capabilities of the user's browser,
- providing a choice of input tools and other mathematical tools.

Performing these tasks in a dedicated service rather than in each individual e-learning tool has several advantages:

- the development effort for mathematics-aware e-learning tools is reduced,
- users only have to specify their preferences once for all e-learning tools,
- the display occurs in a consistent style across all e-learning tools,
- the display methods can more easily be kept up-to date.

This service is particularly important because it ensures that all learning material will be accessible to students with disabilities. This is done automatically behind the scenes without extra effort from the teacher. The ad-hoc methods for the delivery of mathematics used in the past were very problematic in this respect. Our current code name for this service is DOME (Delivering Online Mathematics to Everyone)

The service will be able to translate expressions from OpenMath, MathML or LaTeX format (enclosed by special markup tags) into the most appropriate format for the user. This will be achieved by using a variety of open-source converters. Results of the more time-consuming conversions will be cached for efficiency reasons, using a system already in use in Moodle. The service will probably be defined via WSDL, communicate via SOAP and register itself via UDDI, or alternatively we might use XML-RPC.

The service will be able to evaluate a range of mathematical expressions using an open source computer algebra system (probably Maxima) and to return the result to the calling system.

The service will also deal with markup tags for input elements that will be translated into the user's preferred input tool for mathematics. Instead of a plain text input box the user will be able to choose for example the METRIC tool, which typesets the input, keystroke-by-keystroke, as 2D mathematics.

Finally there will be markup for including a preferences panel or a link to it. For handling of this preference information we will draw on the experience of the CETIS accessibility SIG with the IMS ACCLIP specification.

The user will also be able to start free floating mathematical tools such as various calculator and graph plotting tools already developed for METRIC and WaLLiS and front-ends to server-side computer algebra systems. The application will be able to restrict which tools the service will offer to the user.

Clearly this web service will be valuable not only throughout the higher education sector but also in schools, further education, and job training. We anticipate that many universities and companies will make their services available to other educational web sites free of charge.

Interoperability for mathematics questions

The mathematical questions created by the AiM and METRIC systems are *sui generis*: their internal representations were designed with mathematics in mind, their interoperability with more general systems is limited and their compliance with existing specifications (such as QTI) reflects the lack of mathematics-specific input into those standards.

We will develop and implement an XML specification to allow for mathematics assessment of the type described in section B.1. This will be done in close collaboration with the CETIS SIG on assessment and will build on the existing proposals by Dick Bacon and Manolis Mavrikis. Our specification will be modelled on the latest IMS QTI v.2 standard.

We will implement this specification in three very different systems: AiM, CABLE, and METRIC. The development of the specification and its implementation will proceed in

parallel and will ensure that the specification is practical and realisable in a variety of systems.

We expect that one of our biggest issues will be the semantic encoding of the mathematical expressions. Close consultation with the MathML and OpenMath community and similar concurrent international efforts in other systems (e.g. ActiveMath) will help us address this issue and provide a scalable and interoperable solution.

A mathematical question consists of several elements: question variables that can be randomised or computed from others, answer variables that specify the type of student answer, the question text that can contain these variables, hints, correct answers for answer variables, alternative answers with feedback, and the worked solution that can contain question variables. Variables and answers can be mathematical expressions. The students' answers can be compared with the correct answer (or one of the alternatives) in different ways: mathematical equivalence, numerical precision, or algebraic pattern matching.

Authoring tools for mathematical assessment questions

It is important that authors can create assessment questions easily themselves. Tools for this purpose exist for traditional assessment questions but not for the more sophisticated mathematical assessment questions described above and implemented in AiM, CABLE and METRIC and WaLLiS. We will develop an authoring tool that provides teachers with simple interfaces to design questions without any knowledge of the underlying QTI format.

The authoring tool will have a plug-in architecture that will allow the development of a range of new question types, all of which will get translated into the same underlying XML format. For example there will be dedicated tools for creating integration and differentiation questions that can automatically analyse the student answer for a range of common mistakes and provide the appropriate feedback. The purpose of the plug-in architecture is to allow the user community to easily develop this tool further after the end of the project.

We will also deliver a plug-in for a spreadsheet style question type that will be developed by David Mayston and Tony Ward. This will have a wide area of applications in accounting and finance, which involves both in the UK and internationally a very large potential user community. The question type involves responses that require both numerical and text answers in an organised array with linear relationships between several of the different cell entries. These can take the form of financial statements, such as interlinked Balance Sheets, Profit and Loss Accounts, and Cash Flow Statements, and associated financial and investment analyses for management and investors. The initial financial data specification can be randomised.

The authoring tool will interface with a central repository of assessment questions. Publishing a question to this repository and importing them from there will be a one-click process. The emphasis will be on high-quality questions undergoing further development aided by on-line discussion forums. The repository will be hosted at the University of York until it can be incorporated into JORUM (www.jorum.ac.uk).

Extensible assessment systems

Like the JISC funded APIS project, we will not be delivering an entire new assessment system but only question rendering engines and authoring tools for new question types that shall extend the capabilities of existing assessment systems via web services interfaces. The advantage of this approach is that users who are already familiar with an existing assessment system will be able to use the new question types without having to familiarise themselves with a whole new system. This is particularly important because for many students only some of their courses will need the mathematical question types that we develop and it would not be convenient for these students to have to use different assessment systems in different courses.

This web services architecture also solves the problem of demand peaks. Rendering and marking of mathematical questions can be resource-intensive and if many students take quizzes at the same time, for example in an exam setting, a single question engine can be overloaded. In this case the assessment system can simply send the request to an alternative question engine. This engine could be located on the other side of the globe.

We will collaborate closely with the APIS project in developing the web service protocols so that APIS, AiM and CABLE will all use the same protocol. An assessment system that implements this protocol will be able to use both the QTI v.2 questions that APIS will be able to render and the mathematical question types that we are developing. The services will be defined via WSDL and will communicate using SOAP or will be using XML-RPC.

We will deliver two reference implementations of clients for the new protocol, one in METRIC and one in Moodle. Moodle is an open-source VLE that we are using at York. Through its very intuitive and user-friendly interface and by providing a wide range of collaborative learning tools it is very strong at fostering a community spirit in the learning process, with students helping each other on-line. It also stands out among the open-source VLEs because of its active user and developer community. It has a very well written PHP source code and is easily extensible. This is why we have chosen it as the first system in which we will implement the extensible assessment system architecture.

We will produce a developer's manual that will help the developers of other assessment systems to implement the new web services protocol. We hope that TOIA and the big commercial players will also use this because through APIS and our tools it provides them with an easy way of implementing both IMS QTI v.2 and mathematics-specific capabilities in their assessment systems.

Computer aided problem sheet tools

In order to become popular in university-level mathematics teaching, computer aided assessment has to fit in well with current practice. This practice consists of handing out weekly problem sheets to students, containing challenging problems that the students are expected to work on carefully in their own time. This is very different from most computer aided assessment based on on-line quizzes. We will provide the tools that allow computer aided assessment to be integrated into these problem sheets in such a way that the advantages of both CAA and rational problems sheets are preserved. This means:

1. Lecturers are provided with a unified tool that allows them to manage both their conventional questions (typeset in TeX or LaTeX) and their computerized questions (possibly involving randomisation and computerized feedback and marking).
2. Lecturers can choose from both conventional and computerized questions and assemble them into a problem sheet. The system will create and typeset an individualized version of this sheet for each student and send it to the laser printer.
3. Students can pick up a printed copy of the typeset problem sheet in the lectures or download it from the VLE and take it home to work on. Each printed copy contains an identification number so that the VLE can identify it when answers are entered later.
4. Students hand in the solutions to the conventional questions on paper in the traditional way for hand marking but can get the answers to the computerized problems marked on-line in the VLE.
5. The marking assistants or lecturers enter only the marks for the hand-marked questions into the VLE where they are automatically combined with the marks for the computerized questions.

The tight integration into the VLE is crucial. We will use [Moodle](#) as the initial platform. The system is being used successfully at the University of York. More details can be found in the article "[A conservative approach to computerized marking of mathematical assignments](#)" in the LTSN MSOR CAA series, July 2004.

5. Project Outcomes

The feedback from students using the current systems, and the uptake by teachers, has demonstrated the popularity of our recent approaches to objective testing using sophisticated mathematical tools. Since students' answers are evaluated objectively without the need to select one (or more) teacher-provided answers, we have moved away from the current paradigm of "objective tests", with their well-aided limitations.

We believe we have shown the ability of this approach to improve the learning experience of the students. By providing integration mechanisms for these tools, a wider group of users can enjoy their advantages. We envisage a wider appreciation and use of mathematical assessment or learning tools which objectively test students' answers.

Change takes time, and needs to be carefully planned to ensure the results of change are beneficial, and not detrimental. We envisage that staff new to using the outputs from the project will initially be cautious about their use, and will use them to supplement specific teaching and learning activities. To help in this process we will take great care to ensure low barriers to staff new to this system, both in the design of the learning objects themselves, and through the implementation of the authoring tools we propose to develop.

As confidence builds, staff will appreciate the benefits of generating sophisticated random questions. These allow repeated practice, helping students to become independent learners by deciding how much practice they need themselves, rather than having amounts of work dictated. Changing from setting a "single question" to thinking about a "question space", changes the way staff think about the purpose of their teaching. We expect such pedagogic issues to become more important as the tools become more widely used.

We also envisage more fundamental shifts in pedagogic approaches. For example, since individual students get a unique, but equivalent selection of tasks, genuine group work without plagiarism is now possible in mathematics. Open ended questions, with non-unique correct answers, may also be used to generate discussion and debate in the classroom, and online.

Currently only used significantly in HE, the outputs of this project have enormous potential in schools and for distance and lifelong learning. We envisage wider use across the teaching spectrum.

Finally we hope that a large number of generic e-learning tools will acquire the capabilities necessary for mathematics when other software developers start making use of our web services.

6. Stakeholder Analysis

Stakeholder	Interest / stake	Importance
Lecturers and Teachers	Users	High
Students	Users	High
IMS and CETIS	Input to QTI specification	High
APIS project	Common web services protocol	High
Open-source software developers	Sustainability	High
Commercial software companies	Interoperability	Medium
Publishers	Question banks	Low
JISC	Integration into other projects	Medium
Institutional MLE managers	Interoperability	Medium

Lecturers and other teachers will need to find our tools easy to use and relevant to their teaching methodologies. Because several of the members of the project team are lecturers themselves we have good ideas of what is required and we will let our colleagues test early prototypes for further input.

Students must find the system easy to use for their assessments and the pedagogical benefit must be apparent.

Our proposal for the maths QTI standard will be developed in discussions with CETIS so that it fits well with the existing IMS QTI standard. We would like at least some of our maths extensions to become an official part of the IMS specification.

The APIS project is developing an IMS QTI v.2 question engine and we hope we will be able to agree on a common web services protocol for using APIS and our question engines in extensible assessment systems.

Tools like the ones we develop will profit from ongoing development in response to user's feedback. The version we deliver at the end of this grant must not be the final version. Rather we will design our software and developer's documentation from the beginning with the open-source software community in mind. As has happened with Moodle and AiM, we are

hoping for active involvement from a large number of academics in the further development of the tools.

We hope that commercial software companies will adopt our protocols and use our web services to give mathematics capabilities to their existing e-learning systems. We will welcome representatives from commercial companies to our workshops and will make our developer's documentation available to them. We do however think that the open-source movement holds the most promise and will therefore release all our code under the GPL.

Publishers have started to distribute assessment question banks with some of their textbooks. We would hope that in the future they will use our maths QTI standard for mathematical questions.

The web services architecture of our project is explicitly designed to make it easy to integrate our tools into distributed managed learning environments that are built according to the JISC framework. We hope that institutions realize the value of this framework. We also hope that through JISC it will become known to other JISC funded projects that they could achieve mathematics capabilities by using our services.

7. Risk Analysis

Risk	Probability (1-5)	Severity (1-5)	Score (P x S)	Action to Prevent/Manage Risk
Fragmentation of team	1	4	4	Common protocols and specifications. Frequent communication via several channels
Software problems	2	2	4	Rigorous documentation and tracking mechanisms
Staffing	1	1	1	Duplication of expertise, good documentation
Slippage of deadlines	3	2	6	Early prototypes, last month for exit strategy.
Technical	3	2	6	Well defined interoperability protocols
External suppliers	0	0	0	No reliance on external suppliers
Legal	1	1	1	Open source licenses

The project has team members based at York, Sheffield, Birmingham, Edinburgh and Imperial. This potentially carries the risk of fragmentation. In this project we have the common QTI standard and the common web services protocol that will act as glue. The team manager, Dr Delius, will put a meeting and management structure in place to ensure that the problems of being a distributed team do not hinder progress on the project. Weeklong visits, monthly workshops, regular virtual meetings using Access Grid, and on-line discussions will support collaboration. Several team members are experienced in long-distance collaborations.

Any unforeseen coding difficulties, persistent bugs or “ease of use” problems will be picked up early by rigorous reporting mechanisms, regular meetings, iterative and evaluation-led design and collaborative coding arrangements. The team will respond as necessary by redeploying labour, from site to site if needed.

Any project faces the risk that team members become unavailable due to illness or other reasons. This project is based on five existing software systems and it is a strength that we have developers of each of these on our team: METRIC (PR,DM), AiM (NS,GD), CABLE (CS), WaLLiS (MM) and Moodle (GD,AS). Except for CABLE and WaLLiS the expertise is doubled, if necessary the project could go ahead without them.

The project aims to present interoperable versions of all its deliverables by December and start testing in real-life teaching in January. There is of course the risk that one or several components may not be stable enough by the deadline. Testing would then have to start with fewer components than planned. We think that the risk that any deliverables slip by more than two months is minimal. We are thus confident that we will be able to keep March free for the exit strategy (one-step installers, user-level documentation, and dissemination).

The tools on which this project is based are either already published under an open-source license or the institution where the tools have been developed has already agreed to allow us to publish them under GPL. Thus it is highly unlikely that we would encounter any licensing problems. The only exception is AiM's reliance on the computer algebra system Maple. Maple is a commercial product and its publisher could stop its use in AiM. Should that happen then we will switch the development effort from AiM over to CABLE which works with open source computer algebra systems.

8. Standards

Web services: SOAP, WSDL, and UDDI or XML-RPC

Question and Test Interoperability: We will build on IMS QTI v.2. Details will be discussed at a workshop on September 2nd.

Delivery, representation and presentation of mathematics: We will allow several standards: MathML, OpenMath, TeX, LaTeX as well as non-standardized representation used by computer algebra systems. Our web service will provide for some translation between formats where necessary.

We will try to ensure that all our web user interfaces follow the W3C Web Content Accessibility Guidelines.

Handling of delivery preference information: we will draw on the experience of the CETIS accessibility SIG with the IMS ACCLIP specification.

9. Technical Development

The project will develop existing software tools to make them interoperable by using the same Question and Test Interoperability specification and by making them transact via web

services. Developers working on each software tool will continue to follow the methodology that is being used for that tool.

Further details will be worked out at the developer's meetings and web services workshops in September.

10. Intellectual Property Rights

All of the outputs of this project will be released under the GPL.

This project builds on the following existing tools:

AiM has already been released under the GPL. Unfortunately it requires a copy of Maple to be running on the web server and Waterloo Software, the owner of Maple, could change the licensing rules for Maple so as to disallow its use in AiM.

CABLE is entirely open-source and uses only open-source computer algebra systems. This project will develop CABLE further and release the new version under the GPL.

METRIC is not open source yet but Imperial College, who own the copyright, have officially undertaken to release it under the GPL at the beginning of September as part of their contribution to this project.

Moodle has already been released under the GPL

WaLLiS has a modular design with several components (some of which are already under GPL or no license at all). The IP is currently owned by the School of Mathematics of the University of Edinburgh but it has been officially agreed that they will be released under the General Public License. In addition, WaLLiS employs parts of DANTE (Dynamic Authoring aNd Tutoring Environment) parts of which are already under GPL. Components of DANTE that that need to link and are useful for this project will also be released under GPL.

Project Resources

11. Project Partners

1. University of York

Main contact:	Gustav W Delius Department of Mathematics, University of York, York, YO10 5DD Email: gwd2@york.ac.uk , Phone: (01904) 433 077, Fax: (01904) 433 070
Role:	Lead Institution. Project management. Provides 4 team members. Experience with developing and using Moodle and AiM and with web services.

2. Imperial College, London

Main contact: Philip Ramsden
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Phone: (020) 759 48503, Fax: (020) 759 48517

Role: Provides 3 team members. Developer of METRIC and authoring tools

3. LTSN MSOR Network, Birmingham

Main contact: Chris Sangwin
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Role: 1 team member. Developer of CABLE. Dissemination and community contacts.

4. Department of Mathematics, University of Sheffield

Main contact: Neil Strickland
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Role: 1 team member. Main developer of AiM-tth.

5. School of Mathematics, University of Edinburgh

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Role: 1 team member. Developer of WaLLiS. Expertise on maths QTI

6. Department of Mathematics, Durham University

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Role: 1 team member. Testing of the tools. Experience with AiM in teaching

Supporting letters from all partners were submitted with the original proposal. The nature of this project does not require an additional consortium agreement.

12. Project Management

The project work will be milestone-driven, with one member of the team having responsibility for on-time delivery of each milestone, under the strategic direction of Gustav Delius at York. Within this milestones framework, work will be distributed as flexibly as possible. Expertise will be cascaded, and progress and good practice shared, through on-line discussions and regular meetings of the entire project team.

The core project team is geographically distributed over 5 separate universities. The reason for this is that the project builds on several existing tools and the project team contains developers from each of these tools. These existing tools, as well as 3 new tools to be developed, will be made interoperable by implementing the same web services protocol and interoperability specifications. These special aspects of this project require that special attention is paid to the following management tasks:

1. Agreeing the protocols and specifications
2. Ensuring that development work proceeds smoothly and milestones are reached on time
3. Providing adequate communication between developers

These will now be discussed in turn.

1. Agreeing the protocols and specifications

There are three protocols or specifications that need to be agreed upon:

- maths QTI (a mathematics Question and Test Interoperability specification)
- RemoteQuestionProtocol (a web service protocol for communication between assessment systems and question engines)
- the DOME syntax and protocol (a syntax and web service protocol for communication with the service taking care of the presentation of mathematics on the web)

Each of these requires broad input from the community because we want these specifications to be later taken up by other software tools. We therefore will therefore organize a **workshop** for each of the three specifications. These workshops will be open to all and will be

publicised widely. We will invite external experts. The grant will provide financial support for participants who are likely to make valuable contributions but are unable to fund their participation. After the workshop the discussions will continue on **discussion forums** on the project website. Again these discussions are open to all. For each of the specifications there will be a team member who is responsible for moderating the discussions and using the emerging consensus to draw up draft specifications and post these on the project **website**. These will evolve into final specifications through further discussions gained during implementation of the draft specifications.

2. Ensuring that development work proceeds smoothly and milestones are reached on time

The following milestones and rough timetable were already agreed by the project team and were part of the project proposal:

September	Workshop on maths QTI specification Workshop on web service protocol for extendable assessment systems
October	Release of draft proposal for maths QTI specification Prototype of web service for mathematical expression translation
November	Prototype of authoring tool producing maths QTI Partial implementation of maths QTI in AiM, CABLE and METRIC
December	Release of web service interfaces for Moodle, METRIC, CABLE, AiM, Wallis and the authoring tool Demonstration of interoperability between all components
January	Beta release of all components, ready for testing Final release of proposal for maths QTI specification Authoring tool plug-ins for adaptive questions Release of input and tools part of maths web service
February	Full implementation of maths QTI in AiM, CABLE and METRIC Authoring tool plug-in for spread-sheet style question Authoring tool plug-ins for integration, differentiation, matrix questions Intelligent problem sheets Final releases for all tools
March	Automatic installation packages for all tools User-level documentation. Dissemination workshop

This timetable will be made more precise in the Detailed Project Planning.

In order to allow us to monitor closely the progress towards the milestones and to identify any potential problems early all team members are asked to report regularly through the following channels:

- **Discussion forums:** Each project part has a discussion forum on the project website. Information about all new development will be posted there, as well as requests for testing of new developments and descriptions of any problems that arose. All developers will be subscribed to all forums and will be asked to contribute to answering questions and resolving problems.

- **CVS repository:** All project parts will use a public CVS repository on SourceForge. All new development will be committed to the CVS repository immediately, together with explanatory commit log messages. All code will be documented with sufficient detail to be readable to all. The developer documentation too will be updated in CVS.
- **Nightly blogs:** All full-time developers will keep a blog to which they add every evening, summarizing the day's work. Part-time developers will update their blog only on days that they have spent working on the project. These blogs will be visible to other team members.

3. Providing adequate communication between developers

The project team has 10 developers spread over 5 locations. In order to guarantee good communication we will use the following:

- **Discussion forums** on the project website. Project team members can subscribe to receive emails of all discussion posts.
- **Chat room** on the project website. This provides a channel for synchronous discussions. The discussions are logged.
- **ICQ** instant messaging. While working at a computer the team members will be logged into an ICQ server so that they can be contacted by other team members with urgent questions or requests.
- **Audio conferences** via Teamspeak because sometimes verbal discussions are more efficient than written discussions. However any conclusions reached in these verbal discussions must afterwards be repeated on the discussion forums.
- **Monthly developer's meetings** because our experience has taught us that no kind of electronic communication can replace personal face-to-face interaction.
- **Personal collaborative visits** will take place between team members when this makes the work more efficient, for example because both members' tasks involve similar technology. The duration of these visits will vary between 1 and 5 days.

Here we will list the project team members in alphabetical order together with a list of their main tasks, as they are foreseen currently.

Dr James Blowey (Mathematics, Durham) has introduced AiM at Durham.

- **Tasks:** Testing of our tools in teaching during the spring term at Durham, providing detailed feedback.
- **Time:** 10% for 3 months.

Dr Gustav Delius (Mathematics, York) was responsible for the introduction of Moodle and AiM into the Dept of Mathematics at York. He maintains the AiM project on SourceForge and is contributing to Moodle development.

- **Tasks:** managing the project
- **Time:** 30% FTE for 7 months

Dr Yann Golanski (Mathematics, York) combines a background in physics and mathematics with experience in computing and teaching.

- **Tasks:**
 - Oversee the drafting of the DOME syntax and the DOME web service protocol
 - Implement the DOME service
 - Make Moodle use DOME for mathematics output
 - Create and maintain user documentation, website and support forum for DOME service
 - Maintain the SourceForge CVS repository for DOME
 - Write developer documentation for DOME enabling others to use the service
 - Install and manage the project server
 - Write authoring tool plug-in for spreadsheet style questions
- **Time:** 100% FTE for 6 months

Mr Mark Jessop (Computer Science, York) has been one of the leading software architects within the £3.2million EPSRC e-Science Pilot Project, DAME (<http://www.cs.york.ac.uk/dame>). He has extensive experience with the design of distributed systems based upon web service and grid service models, and will bring extensive experience to the consortium in regard to the design and deployment and web service technology.

- **Tasks:**
 - provide training on web services to team members
 - help with the development of web services interfaces for all components of the project
- **Time:** 20% FTE for 4 months

Mr Manolis Mavrikis (Mathematics, Edinburgh) has been developing WaLLiS for the last three years. He is collaborating closely with the LeActiveMath FP6 keeping the underlying representation of WaLLiS and ActiveMath close. As member of the CETIS Assessment SIG he has identified problems of IMS QTI and presented solutions. His PhD research is on building intelligent tutoring systems to target students' misconceptions by providing intelligent and adaptive feedback.

- **Tasks:**
 - Organise the workshops related to mathematics specifications
 - Moderate a related discussion forum
 - Oversee the drafting of a specification for mathematical questions
 - Make WaLLiS an RQP client,
 - Make WaLLiS use DOME for mathematics output and input
 - Write an authoring tool plug-in for adaptive questions
- **Time:** 30% FTE for 6 months

The following three members form the Imperial College team:

Dr Daniel May (Mathematics, Imperial) joined the METRIC project in August 2000 and has since co-authored the METRIC system. He has attended the "ml and technologies for math on the web" conference and has recently been working on migrating the METRIC system to use MathML. Expertise: Java programming, XML, XML Schema, XSL and

MathML.

Time: 40% FTE for 7 months

Mr Phil Ramsden (Mathematics, Imperial) was appointed to Imperial as a mathematical e-learning specialist in 1993. He is an expert in computer algebra and has hosted the International Mathematica Symposium at Imperial. He has attended, and presented at, conferences on mathematical pedagogy, where his special interest is the use of computer technology in teaching and learning. Special skills: Java representation of maths expressions, parameterisation and interpolation, mathematical graphics, mathematical pedagogy.

Time: 40% FTE for 7 months

Programmer (Mathematics, Imperial)

Time: 100% FTE for 6 months

- **Tasks for the Imperial College team:**
 - Oversee the specification of the authoring tool plug-in architecture
 - Develop the question authoring tool
 - Create and maintain user documentation, website and support forum for authoring tool
 - Maintain the SourceForge CVS repository for authoring tool
 - Create and maintain a repository for maths QTI questions
 - Develop interface between authoring tool and maths QTI repository
 - Implement rendering and marking of maths QTI questions in METRIC
 - Implement RQP client interface in METRIC
 - Make METRIC use DOME for mathematics output and input
 - Contribute METRIC's mathematical tools to the DOME service

Dr Chris Sangwin (Mathematics, Birmingham and LTSN MSOR network) undertakes mathematics education research, with a focus on computer aided assessment. His expertise includes mathematics pedagogy, and he has been invited to speak about the AiM system at national and international conferences. Through the LTSN he has promoted the use of AiM, and he runs the aim@jiscmail.ac.uk list.

- **Tasks:**
 - Implement RQP server interface in CABLE
 - Implement rendering and marking of maths QTI questions in CABLE
 - Write authoring tool plug-ins for differentiation questions, integration questions, matrix questions
 - Make CABLE use DOME for mathematics output and input
 - contribute CAS support to DOME
- **Time:** 100% FTE for 4 months, 50% FTE for 3 months

Mr Julian Sedding (Computer Science, York)

- **Tasks:**
 - Integrate the question authoring tool into Moodle.
 - Develop Computer Aided Problem Sheets (CAPS) tool (with Alex)
 - Integrate CAPS into Moodle (with Alex)
 - Write teacher manual and student tutorial for CAPS
 - Produce a collection of example problem sheets.

- Produce developer documentation and manage SourceForge CVS repository for CAPS
- **Time:** 100% FTE for 7 months

Mr Alex Smith (Mathematics, York) has tailored Moodle for the Dept of Mathematics at York, developed new features and a module to interface with the AiM.

- **Tasks:**
 - Oversee the drafting of the RemoteQuestionProtocol.
 - Extend the Moodle quiz module so that it is an RQP client, thereby integrating all RQP services into Moodle.
 - Write developer's documentation to make it easier for developers of other assessment systems to implement RQP.
 - Collaborate with Chris on CABLE work
 - Develop Computer Aided Problem Sheets (CAPS) tool (with Julian)
 - Integrate CAPS into Moodle (with Julian)
- **Time:** 100% FTE for 7 months

Prof Neil Strickland (Mathematics, Sheffield) is the author of the current version of AiM (a complete redesign and extension of an earlier version written by Theodore Kolokolnikov and others). He is an expert on the use of computer algebra systems for research, and for the generation of animated and interactive graphics for teaching, as well as for computer aided assessment.

- **Tasks:**
 - Implement RQP server interface in AiM
 - Implement rendering and marking of maths QTI questions in AiM, building on similar work for CABLE,
 - Make AiM use DOME for mathematics output and input
- **Time:** 20% FTE for 7 months

Indicate if the project has training needs and how they will be met.

Project members will train themselves and each other on the job. We have a diverse spectrum of expertise within our team and intend to spread this in the project through personal collaboration and through exchange of knowledge on the discussion forums. Much will be learned by reading, again helped by being guided to the relevant literature by other project members. Each of the monthly developer's meetings will have short tutorials given by a team member.

13. Programme Support

We do not, at this point, have any special needs for support.

14. Budget

The budget with explanations is attached in Appendix A

The further sections below will be filled in at a later stage.

Detailed Project Planning

15. Workpackages

Use the workpackages template to plan the detailed project work and attach as Appendix B. Clearly indicate project deliverables and reports (in **bold**), when they are due, phasing of workpackages, and explain any dependencies. You may also attach a Gantt chart, diagram, or flowchart to illustrate phasing.

16. Evaluation Plan

Indicate how you will evaluate the quality of the project outputs and the success of the project. List the factors you plan to evaluate, questions the evaluation will answer, methods you will use, and how success will be measured. Expand as appropriate on how you will conduct the evaluation.

Timing	Factor to Evaluate	Questions to Address	Method(s)	Measure of Success

17. Quality Assurance Plan

Explain the quality assurance procedures you will put in place to ensure that project outputs comply with JISC technical standards and best practice, and what will constitute evidence of compliance.

Timing	Compliance With	QA Method(s)	Evidence of Compliance
	Fitness for purpose		
	Best practice for processes		
	Adherence to specifications		
	Adherence to standards		
	Accessibility legislation		

18. Dissemination Plan

Explain how the project will share outcomes and learning with stakeholders and the community. List important dissemination activities planned throughout the project, indicating purpose, target audience, timing, and key message.

Timing	Dissemination Activity	Audience	Purpose	Key Message

19. Exit/Sustainability Plan

Explain what will happen to project outputs at the end of the project (including knowledge and learning). Focus on the work needed to ensure they are taken up by the community and any work needed for project closedown, e.g. preservation, maintenance, documentation.

Project Outputs	Action for Take-up & Embedding	Action for Exit

List any project outputs that may have potential to live on after the project ends, why, how they might be taken forward, and any issues involved in making them sustainable in the long term.

Project Outputs	Why Sustainable	Scenarios for Taking Forward	Issues to Address

Appendixes

Appendix A. Project Budget

Staff costs:

James Blowey	£1,310	10% Jan - March, point 24
Gustav Delius	£7,679	30% Sept - March, point 18
Yann Golanski	£17,518	Oct - March, point 12
Mark Jessop	£2,752	20% Sept - Dec, point 16
Manolis Mavrikis	£4,819	30% Oct - March
Daniel May	£8,487	40% Sept - March
Phil Ramsden	£12,168	40% Sept - March
Chris Sangwin	£15,572	Full time Sept-Dec, half time Jan-March
Julian Sedding	£15,286	Sept - March, point 6
Alex Smith	£15,286	Sept - March, point 6
Neil Strickland	£5,000	20% Oct - March
Programmer	£15,229	Oct - March
Secretary (York)	£2,127	20% Sept - March, point 16. See 1)
Secretary (Imperial)	£1,778	10% Sept – March. See 1)

Other costs:

Maths QTI workshop	£300	See 2)
RQP workshop	£300	See 2)
DOME workshop	£300	See 2)
Web services tutorial	£300	See 3)
Monthly developers meetings	£1,500	6 meetings for all developers. See 4)
Attending JISC meetings	£300	
Attending CETIS meetings	£300	See 5)
Collaborative visits	£800	See 6)
2 working visits by Palomo	£900	See 7)
Visits from external experts	£600	See 8)

Computers for new staff	£3,600	See 9)
Project server	£900	See 10)
Consumables at York	£1,000	printing, books, fax, telephone, stationery
Consumables at Imperial	£1,000	printing, books, fax, telephone, stationery
Consumables at Birmingham	£400	printing, books, fax, telephone, stationery
Consumables at Edinburgh	£400	printing, books, fax, telephone, stationery
Total:	£137,911	

Notes:

1. Secretarial support is required to do the financial paperwork, organize the many workshops, the visits from external experts, and the travel of team members and to help with documentation and the website.
2. We are organizing three workshops to get the widest possible input into the new mathematical Question interoperability specification, the new Remote Question Protocol, and the DOME service for mathematical expressions. This workshop is advertised to the relevant mailing lists and subsidy of travel costs is offered to participants.
3. Web services protocols play a central role in our project. To get us started Mark Jessop will give a one-day tutorial to all team members.
4. This is not a straightforward project, there are many technical issues to discuss, strategies to be decided, specifications to be agreed. This necessitates regularly scheduled workshops where all developers meet. To minimize travel costs, most meetings will take place at York.
5. Our project is heavily based on standards. In some cases we will need to extend the standards. The experience we gain will be of value to the community and the CETIS SIG meetings, e.g. the Assessment SIG and the Accessibility SIG, provide a good forum to share this experience with the interested persons. Also we wish to learn from the experience of others at these meetings.
6. While it is true that each geographic node of this project works on a well defined subproject, there is overlap in the required expertise. It will thus occasionally be more productive for a team member to perform the work while visiting another node. For example Chris Sangwin will be visiting York several times for two to three days, for example to share expertise in implementing web services in PHP and to contribute experience with computer algebra systems to the DOME project.
7. Alberto Gonzalez Palomo is a valuable member of the FP6 ActiveMath project, and the OMDoc and OpenMath communities. His expertise in identifying the underlying structure of the exercises in ActiveMath will be essential for this project. Alberto has build an open source authoring tool (QMath), has contributed to several open source projects including Yacas, and has built several translators from OpenMath to CAS syntax and from OpenMath to XHTML. Having him in the project will reduce the amount of duplicated work for the authoring tool and the transformations between several mathematical encodings.
8. There are several people in the community who have already done a lot of work on solving the specific issues of mathematics in e-learning. It will help our project immensely if we will be able to draw on their experience by inviting them to visit us.
9. We are no longer budgeting for computer provision for existing university staff. However the project will hire 4 people who will not be in regular university employment and will therefore not be entitled to computer provision. Clearly computer provision is essential to their development work. The computers will stay

with the project after the grant and will be made available to people contributing to the further development of the project.

10. The software tools that the project develops are mostly web server based. We thus need a dedicated web server for development and testing. After the end of the project this server will continue to serve our web services tools for free use by the community.

Appendix B. Workpackages

JISC Project Management Framework
22 December 2003